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ORIGINAL ARTICLE

The effect of harp music on heart rate, mean blood pressure, respiratory rate, and body temperature in the African green monkey

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Keywords
cardiovascular – *Chlorocebus aethiops* – cytocymatics – environmental enrichment – relaxation – stereotypies – stress – telemetry

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Abstract

Background The effectiveness of recorded harp music as a tool for relaxation for non-human primates is explored in this study.
Methods Konigsberg Instruments Model T27F-1B cardiovascular telemetry devices were implanted into nine African green monkeys (*Chlorocebus aethiops*). After post-surgical recovery, animals were exposed to recorded harp music. Telemetry data were collected on heart rate, mean blood pressure, respiratory rate, and body temperature for a 30-minute baseline period before music exposure; a 90-minute period of music exposure; and a 90-minute post-exposure period, where no music was played.
Results No statistical differences were noted in heart rate, mean blood pressure, respiratory rate, and body temperature between pre-exposure, exposure, and post-exposure periods.
Conclusions The lack of response in these African green monkeys may be attributable to their generally calm demeanor in captivity; experiments with a more excitable species such as the rhesus macaque might demonstrate a significant relaxation response to music.

Introduction

While in captivity, non-human primates (NHPs) have been known to develop aberrant behaviors and stereotypies. Many of these behaviors, if not ingrained from early development, may arise as a response to being in captivity, housed singly, or both [1]. Since the 1985 amendment to the Animal Welfare Act mandating that captive NHPs be afforded an environment to promote their psychological well-being, a myriad of enrichment tools and tactics have flooded the market, targeting mainly the gustatory, tactile, and visual senses as well as incorporating the species-specific behaviors of foraging and grooming.

The use of music as an enrichment tool for wild, captive, and pet animals is not a new concept [6, 11, 18, 24]. Music has also been used successfully as part of human therapy programs for chronic pain sufferers, psychiatric disorders, and other maladies [2, 4, 5, 7, 8, 10, 14, 23, 25, 26, 28]. Harp music specifically has demonstrated healing effects for both animals and humans [21]. The study of how sound affects cellular material (cytocymatics) is the basis for this enrichment therapy [21]. Specific modes in music with resulting tones, harmonics, overtones, and all associated frequencies are the foundation for evaluating and providing acoustical nourishment for the individual in need. Potential outcomes and benefits include lowered heart rate, pulse, blood pressure, and respirations with increased oxygenation; general reduction of agitation; decreased stress and anxiety; increased endorphin levels; and quicker recovery in post-surgical conditions [2–5, 7, 10, 13].

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14. ABSTRACT

Background: The effectiveness of recorded harp music as a tool for relaxation for nonhuman primates (NHP) is explored in this study. Methods: Konigsberg Instruments Model T-27F-1B cardiovascular telemetry devices were implanted into nine African green monkeys (Chlorocebus aethiops). After post-surgical recovery, animals were exposed to recorded harp music. Telemetry data were collected on heart rate, mean blood pressure, respiratory rate, and body temperature for a 30-minute baseline period before music exposure; a 90-minute period of music exposure; and and a 90-minute postexposure period, where no music was played. Results: No statistical differences were noted in heart rate, mean blood pressure, respiratory rate, and body temperature between pre-exposure, exposure, and postexposure periods. Conclusions: The lack of response in these African green monkeys may be attributable to their generally calm demeanor in captivity; experiments with a more excitable species such as the rhesus macaque might demonstrate a significant relaxation response to music.

15. SUBJECT TERMS

cytocymatics, stress, Chlorocebus aethiops, relaxation, environmental enrichment, sterotypies, telemetry, cardiovascular

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Studies with music as enrichment for animals have documented subjectively and indirectly the effects of different musical treatments and therapy [18, 21]. We hypothesized that the use of harp music as environmental enrichment, specifically as an aid to relaxation, for African green monkeys would be associated with decreases in heart rate, mean blood pressure, body temperature, and respiratory rate as measured by intrathoracic cardiovascular telemetry devices.

Materials and Methods

Research was conducted in compliance with the Animal Welfare Act and other federal statutes and regulations relating to animals and experiments involving animals and adheres to principles stated in the *Guide for the Care and Use of Laboratory Animals*, National Research Council, 1996. The facility's Laboratory Animal Care and Use Committee approved all research conducted in this study. The facility where this research was conducted is fully accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International.

Animals

Caribbean origin African green monkeys (*Chlorocebus aethiops*) were selected for containment studies at the United States Army Medical Research Institute of Infectious Diseases. Animals were housed individually with visual, auditory, and olfactory contact with each other. Over several months, animals were brought successively onto the study, with as many as five being housed in the same room together. The total number of animals used for this study was 9.

Animals were given health examination at the beginning of their addition to the containment studies, and included clinical chemistries and hematologies. No abnormalities were noted at the time of this physical examination. Animals were negative for tuberculosis, SA8, simian immunodeficiency virus, simian T-cell leukemia virus, and measles virus. Animals were maintained on standard monkey chow (Harlan Teklad, Madison, WI, USA) and water *ad libitum*, as well as a standard 12:12 hour light:dark cycle. Room temperature was maintained between 64 and 84°F and relative humidity between 30% and 70%. The institute's enrichment program for NHP includes interval food treats and manipulanda (Kong toys, balls, mirrors, rattles), all of which were made available to these animals. All animals were naïve subjects before the start of the study with no known previous exposure to any music or any other experimental procedure.

Surgery

In preparation for the containment studies, each animal was implanted with the Konigsberg Instruments Model T27F-1B telemetry device [Data Integrated Scientific Systems (DISS), Pinckney, MI, USA] (Fig. 1). Surgical methods were followed according to the manufacturer's instructions and included placing a ventricular pressure transducer into the left ventricle of the heart, an aortic pressure transducer into the lumen of the aorta, an intrathoracic pressure transducer between the 11th and 12th ribs against the pleural membrane, and the tip of an electrocardiogram (ECG) lead to the posterior surface of the deep pectoral muscle. All transducers and the ECG lead connected to a transmitter and battery pack placed between the layers of the abdominal oblique musculature with an antenna extending subcutaneously from this site to the left flank area. The entire implantation procedure was completed within 3 hours. Animals were recovered from anesthesia and maintained in their original cages for 30 days before this study, allowing their complete healing and recovery. Animals were given buprenorphine intramuscularly (0.01 mg/kg) three times per day for 48 hours following surgery. Buprenorphine was discontinued for at least 28 days prior to the beginning of this study.

Study design

During the interval after surgical recovery and before the animals were moved to the containment laboratory, recorded harp music [19] was played as part of the enrichment schedule. During different hours on different days recorded harp music was played in the room with the monkeys, and data were acquired for

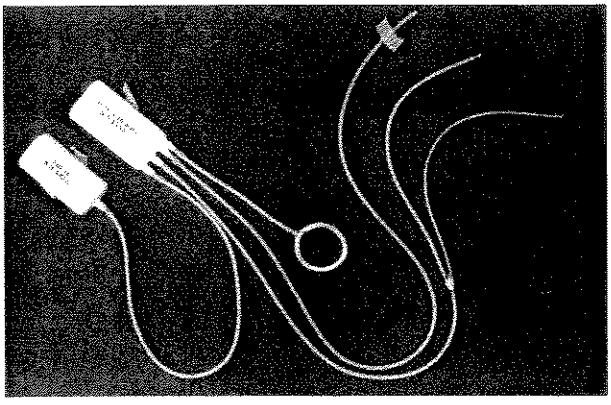

Fig. 1 The Konigsberg Instruments T27F-1B Cardiovascular Implant monitors up to three channels of pressure, including respiration, plus ECG and temperature. Total implant weight = 78 g. Electronic module = 5.0 × 2.5 × 1.0 cm^3. Battery module = 5.0 × 3.0 × 1.0 cm^3.

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later analysis. Hours of music application included the following time periods: 09:00–10:30, 10:00–11:30, 11:00–12:30, 13:00–14:30 and 13:30–15:00 hours. Based on data recorder and animal availability, the minimum number of data recording sessions was two per animal and the maximum number of data recording sessions was 10 per animal.

Thirty minutes before music application, the usual room activity was allowed to continue, and included cage cleaning, feeding, interaction with the animals, room cleaning, or entry to check on the data acquisition equipment. The time between prior room activity and music onset was not noted. Music was played for 90-minute periods. While music was played, no one entered the room, however, the usual hallway activity was permitted outside the room. Hallway activity varied from completely quiet to variously noisy, depending on the usual institute activities (movement of cage racks, people talking, or training sessions and protocol support continuing in the nearby lab). Even the noisiest hallway activity was intermittent and did not last the full 90-minute period of music application. Once music was stopped, room entry was restricted further for another 90 minutes.

Heart rate, mean blood pressure, body temperature, and respiratory rate were selected for analysis. Responses were analyzed 30 minutes prior to music being played (baseline); 90 minutes during music application (music on); and 90 minutes after music was played (music off). During the 'music on' period, responses were analyzed in three 10-minute segments, then two 30-minute segments. The 90-minute post-exposure segment (music off) was analyzed in three 30-minute segments. For each animal, averages were calculated for each segment of time in the session.

Data acquisition

The CA Recorder Data Acquisition and Analysis System® (Version 2.2.4.4; DISS, LLC) [9] was set up in the animals' room for data acquisition. Originally four monkeys were recorded at one time, after which the main recording unit was moved to the containment suite for use there. In its place a second, smaller unit was installed which allowed only two animals to be recorded at the same time. For each monkey, a user-defined subject template was automatically applied, to create an accurate and consistent configuration across all subjects. This template included establishing appropriate settings for visual tracings from signals from the cardiovascular implant for ventricular pressure, aortic pressure, intrathoracic pressure, temperature, and ECG. Values for heart rate (beats per minute), mean blood pressure (mmHg), body temperature (°F), and respiratory rate (breaths per minute) were derived from these *in vivo* measurements. The configuration assured the same analysis, sampling rates, corrections, and calibration across all subjects.

All data were acquired every 5 s over 24 hours. For each monkey the time periods of interest were excerpted from the 24-hour data collection using CA Recorder® and then analyzed (VR^2® Data Management and Verification Tool, Version 1.1.48; DISS, LLC). Where applicable, noise was suppressed and removed from data analysis.

Statistical analysis

Data points used for analysis were summary data produced by VR^2® (Version 1.1.48, DISS, LLC). Extracted data averages were calculated in VR^2® and imported into SAS® Version 9.1 for subsequent analysis.

The number of intervention sessions varied within the sample. One animal was exposed for two sessions. Four animals were exposed for four sessions. Two animals were exposed for five sessions. Two animals were exposed for 10 sessions. In order to reduce the number of missing data points, analysis with all nine animals was limited to the first five sessions. A mixed-model ANOVA [15] was used to analyze the data, with period during intervention used as a repeated effect and session used as a random effect.

Results

All animals recovered completely from the cardiovascular implant surgery. During the placement of the aortic pressure transducer, the descending aorta was clamped. One animal developed a temporary hind limb paresis following surgery that last 24 days. No other complications associated with surgery, recovery, or post-surgery were noted for any other subject.

There were no statistical differences in heart rate ($P = 0.8359$), mean blood pressure ($P = 0.2448$), body temperature ($P = 0.3730$), and respiratory rate ($P = 0.1284$), between the periods of pre-exposure to music (baseline), exposure to music (music on), and post-exposure to music (music off) (Table 1). There were no statistical differences between the different times of day chosen for music application. Trends indicated a slight increase in heart rate and mean blood pressure at the beginning of the music period, with a return to baseline conditions. After music application, during the 90-minute period of undisturbed silence, trends showed a continued, slight decline in heart rate. This

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slight decline usually leveled off within 2 hours after music was discontinued. Heart rate and blood pressure then returned to baseline between 15 and 60 minutes later, depending on when normal room activity was restored.

Table 1 Results of the mixed-model ANOVAs showing no significant change over intervention time periods nor a significant change between sessions for any of the physiologic variables measured

Variable	Period (min)	N	Mean	SD
Heart rate (beats/min)				
Baseline (no music)	30	37	99.84	31.24
Music on	10	37	103.73	36.55
	10	37	101.14	35.04
	10	37	99.14	40.02
	30	37	99.51	29.93
	30	37	100.43	37.69
Music off	30	37	96.43	33.99
	30	37	97.76	32.16
	30	35	96.03	32.43
Mean blood pressure (mmHg)				
Baseline (no music)	30	29	78.79	16.80
Music on	10	29	80.93	20.38
	10	29	80.66	19.61
	10	29	79.17	17.62
	30	29	78.62	17.13
	30	29	77.52	16.85
Music off	30	29	79.17	17.89
	30	29	78.38	15.72
	30	27	77.89	17.33
Temperature (°F)				
Baseline (no music)	30	37	36.69	0.84
Music on	10	37	35.80	5.97
	10	37	35.82	5.95
	10	37	35.85	5.98
	30	37	38.85	5.95
	30	37	36.80	0.74
Music off	30	37	36.82	0.61
	30	37	36.86	0.56
	30	35	36.85	0.56
Respiratory rate (breaths/min)				
Baseline (no music)	30	26	29.19	4.01
Music on	10	26	29.42	4.26
	10	26	30.46	4.82
	10	26	30.00	4.95
	30	26	29.04	4.16
	30	26	28.31	3.72
Music off	30	25	28.68	4.64
	30	26	28.50	4.85
	30	24	29.04	4.99

Results show mean and standard deviation (SD) values for heart rate, mean blood pressure, temperature, and respiratory rate for the time periods indicated. N = the number of sessions recorded for each period.

Discussion

African green monkeys are fast becoming the leading choice of NHP for many types of biomedical research studies, for their ease of acquisition, reduced procurement expense, and reduced risk of Cercopithecine herpesvirus type 1 exposure, when compared with macaques. African green monkeys are generally more adaptable to cage environments and evidence fewer stereotypies and other behavioral problems than captive macaques. Although some may show aggression at a viewer, more frequently they are quiet, observant animals without outward signs of agitation or stress. It stands to reason that very few physiologic changes would occur in conjunction with music used for relaxation.

The parameters of heart rate, mean blood pressure, body temperature, and respiratory rate were chosen mainly because these parameters have been studied extensively in human subjects undergoing music therapy as a treatment for stress [2, 4, 5, 7, 12, 13, 16, 26, 28]. They are uniformly used throughout the clinical nursing industry as indicators of stress levels in human patients [13, 23, 28]. Although the music did not have a measurable effect on these physiologic variables in the African green monkey, it may have had some effect on behaviors that were not examined in this study, such as activity in the cage, vocalization, eye contact with other subjects, posture changes (to include lying down), or sleeping. A natural progression from consciousness (awake behaviors) to a state of unconsciousness (sleeping) has been observed in captive animal populations exposed to live harp music [22, 27]. A state of deep relaxation in animals presumably would evidence significant drops in heart rate, blood pressure, and respiratory rate, as noted in human studies [5, 8, 10, 13]. The video feature available with CA Recorder® was not in place during this study, but may be used in future studies to assess behavioral changes.

Regarding the upward trends noted in blood pressure and heart rate at the beginning of the music period, the novelty of music may generate a 'startle' response initially within the first 10–20 minutes, but then a subsequent adaptive period is observed. This is what is commonly reported by humans undergoing music therapy, when blood pressure and heart rate are measured [16, 17]. After music was discontinued, the heart rate was observed to decline slightly, which may indicate a continued sedentary state.

In this study only nine subjects were available for analysis. Although there may be changes in the chosen parameters, the changes may be so small that one

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cannot detect them with the small sample size. There was wide variability in mean blood pressure and heart rate especially.

Music was played at different times and not always on succeeding days. The same enrichment given for prolonged periods ceases to lose its novelty and effect [1]; playing music continuously may elicit an adaptive response or a complete disregard for the enrichment altogether. The authors also did not restrict completely the normal activity associated with living in an NHP room, including auditory access to daily noises outside the room. In this manner the authors hoped to capture the animals' responses in the context of a usual day or week at the institute.

Measuring these parameters *in vivo* in macaques exposed to music for relaxation would be a worthy next step. Knowing that many macaque species are by nature more aggressive and active, the use of harp music may have a more pronounced relaxation effect on them [27]. Another logical next step is to pursue more closely the NHP's responses to different kinds of music, to include responses to harp music with those of classical, country, rock, or other types. Work continues on the application of cytocymatics with different species, learning what frequencies stimulate relaxation behaviors [20, 22, 27].

Recorded harp music did not provide significant physiological benefit to African green monkeys due to their normally sedate behavior compared with other species. Facilities relying solely on music as enrichment for this species may wish to re-evaluate their enrichment techniques to find more beneficial ways to enhance the monkeys' environment. Further research is attainable on this important topic, and these types of studies can be integrated easily into other studies that use advanced data collection techniques, with minimal additional cost and impact on other resources. Implantable telemetry devices show tremendous potential for obtaining objective data to contribute to science-based information on issues of animal welfare.

Regardless of NHP species, the use of music as an addition to any environmental enrichment program should not be discounted. As an added form of enrichment targeting the auditory sense, music may serve to distract, relax, or comfort captive animals.

Disclaimer

Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the U.S. Army.

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